REMARKS

In view of the above amendments and the following remarks, reconsideration of the objections and rejections set forth in the Office Action of November 2, 2005 is respectfully requested.

On page 2 of the Office Action, the Examiner indicated that the Applicants' proposed change to the specification presented in the Amendment filed September 20, 2005 constituted new matter, and required that the proposed change be cancelled. In particular, the Examiner asserted that the proposed change was not supported by Figure 9 as asserted by the Applicants.

Without acquiescing to the Examiner's assertion, the specification has now been amended as indicated above. In particular, the original proposed language has been deleted, but alternate language describing the difference between the flank 41b and the chamfer 41c shown in Figure 9 of the present application has been inserted. In particular, the specification has now been amended to explain that the degree of curvature of the large rib surface 41 changes from the flank 41b to chamfer 41c. The Applicants submit that this feature is *clearly* illustrated in Figure 9. Thus, this change does not constitute new matter. Moreover, the specification has been amended to indicate that the magnitude of the curvature of the point on the large rib surface connecting the flank 41b to the chamfer 41c is larger than the magnitude of curvature of either the flank 41b or the chamfer 41c. Again, it is submitted that this feature is *clearly* illustrated and therefore supported by Figure 9. Thus, this change also does not constitute new matter. For the Examiner's benefit, prints-out from several web pages generally explaining curvature and degree of curvature have been submitted herewith. In view of the above, the Examiner is respectfully requested to enter the amendments to the specification.

The Examiner rejected claims 21, 22, 26, and 27 as being anticipated by the Yasui reference (US 4,523,862); and rejected claims 23, 24, 28, and 29 as being unpatentable over the Yasui reference in view of official notice of common knowledge in the art. In particular, the Examiner asserted that Figure 4 of the Yasui reference teaches a flange with an outer edge having both a flank (radially inner portion) and a chamfer (radially outer portion). However, independent claims 21 and 26 have now been amended as indicated above. In particular, as

illustrated in Figure 9, these claims recite that the large rib surface 41 of the inner ring 40 has a conical surface 41a for contacting large end faces 43 of a tapered roller 42, a flank 41b smoothly connected to the conical surface 41a and curving away from the large end faces 43 of the tapered rollers 42, and a chamfer 41c connected to a radially outer edge of the flank 41b.

Furthermore, amended independent claims 21 and 26 now recite that a degree of curvature of the large rib surface 41 *changes from the flank 41b to the chamfer 41c*. In other words, the degree of curvature of the large rib surface 41 is *not* uniform. In view of this arrangement, the wedge angle defined by the flank 41b can be optimally adjusted completely independent of the chamfer 41c. Thus, a wedge-shaped space can be defined between the flank and the large end face of each of the tapered rollers so as to smoothly draw lubricating oil into the wedge-shaped space and thereby prevent damage to the large end faces of the tapered rollers even if the tapered rollers are skewed relative to the inner ring during operation.

Conventional roller bearings, such as the tapered roller bearing of the Yasui reference, do not include or even suggest a large rib surface having a flank and a chamfer with the shape and arrangement recited in amended independent claims 21 and 26. In the outstanding Office Action, the Examiner asserted that Figure 4 of the Yasui reference illustrates a flank (radially inner portion) and a chamfer (radially outer portion) of a curved surface at a radially outer edge of a surface corresponding to the large rib surface recited in independent claims 21 and 26. However, as clearly illustrated in Figures 1, 4, 5, and 7 of the Yasui reference, the outer edge of the surface identified by the Examiner as apparently corresponding to the large rib surface of the present invention curves in a uniform manner (i.e., has a uniform, constant degree of curvature throughout the curved surface). Therefore, although the Examiner asserted that this curved surface includes both a flank and a chamfer, this curved surface of the Yasui reference does not include a flank and chamfer in which *the degree of curvature of the large rib surface changes from the flank to the chamfer*. Therefore, one of ordinary skill in the art would not be motivated by the Yasui reference to obtain the invention as recited in amended independent claims 21 and 26. Accordingly, it is respectfully submitted that amended independent claims 21 and 26, and the claims that depend therefrom, are clearly patentable over the prior art of record.

In view of the above amendments and remarks, it is submitted that the present application is now in condition for allowance. However, if the Examiner should have any comments or suggestions to help speed the prosecution of this application, the Examiner is requested to contact the Applicant's undersigned representative.

Respectfully submitted,

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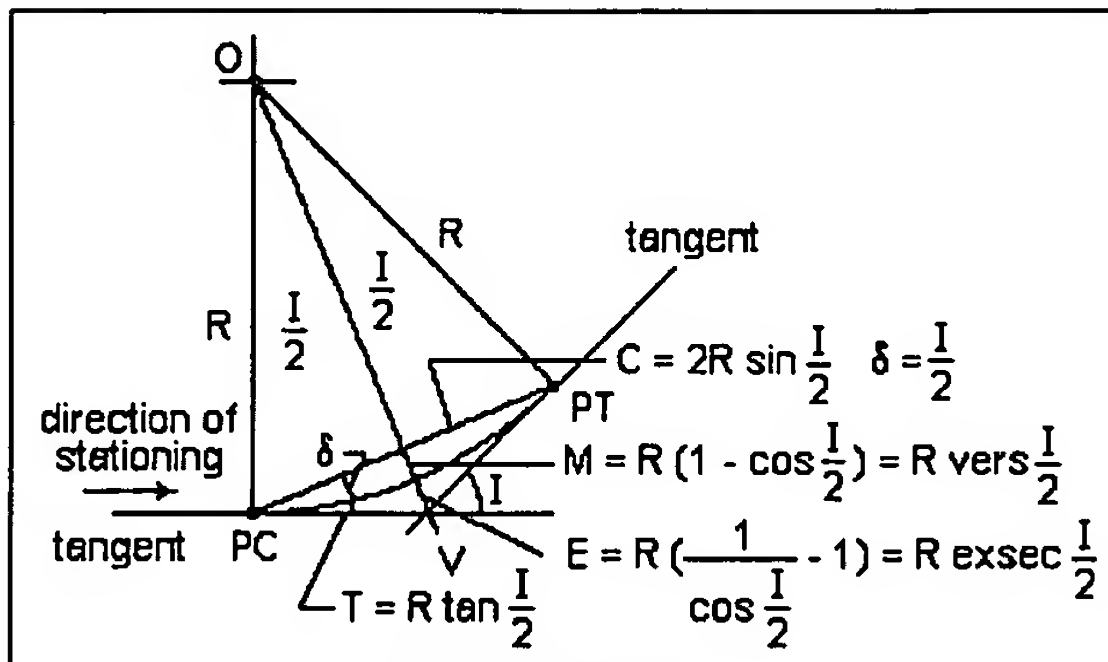
February 2, 2006

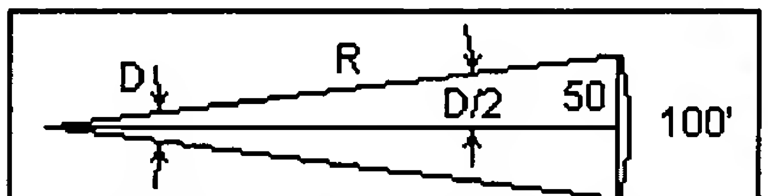
US APPLICATION SERIAL NO. 10/649,764

Degree of Curvature



Circular Curve

A circular curve is often specified by its radius. A small circle is easily laid out by using the radius. In a mathematical sense, the *curvature* is the reciprocal of the radius, so that a smaller curvature implies a large radius. A curve of large radius, as for a railway, cannot be laid out by using the radius directly. We will see how the problem of laying out a curve of large radius is solved. In American railway practice, the radius is not normally used for specifying a curve. Instead, a number called the *degree of curvature* is used. This is indeed a curvature, since a larger value means a smaller radius. The reason for this choice is to facilitate the computations necessary to lay out a curve with surveying instruments, a transit and a 100-ft engineer's tape. It is more convenient to choose round values of the degree of curvature, rather than round values for the radius, for then the transit settings can often be calculated mentally. A curve begins at the P.C., or point of curvature, and extends to the P.T., or point of tangency. The important quantities in a circular curve are illustrated above.



Definition of Degree of Curve D

The degree of curvature is customarily defined in the United States as the central angle D subtended by a *chord* of 100 feet. The reason for the choice of the chord rather than the actual length of circumference is that the chord can be measured easily and directly simply by stretching the tape between its ends. A railway is laid out in lengths called *stations* of one tape length, or 100 feet. This continues through curves, so that the length is always the length of a series of straight lines that can be directly measured. The difference between this length, and the actual length following the curves, is inconsequential, while the use of the polygonal length simplifies the calculations and measurements greatly.

The relation between the central angle d and the length c of a chord is simply R sin(d/2) = c/2, or R = c/(2 sin d/2). When c = 100, this becomes R = 50/sin D/2, where D is the degree of curvature. Since sin D/2 is approximately D/2, when D is expressed in radians, we have approximately that R = 5729.65/D, or R = 5730/D. Accurate values of R should be calculated using the sine. For example, a 2° curve has R = 2864.93 (accurate), while 5730/D = 2865 ft.

If some other value and length unit are chosen, simply replace 100 by the new value. In the metric system, 20 meters is generally used as the station interval instead of 100 ft, though stations are numbered as multiples of 10 m, and these equations are modified accordingly. With a 20 m chord, R = 1146/D m,or about 3760/D ft. Of course, a given curve has different degrees of curvature in the two systems. There are several methods of defining degree of curvature for metric curves. D may be the central angle for a chord of 10 m instead of 20 m.

The deflection from the tangent for a chord of length c is half the central angle, or δ = d/2. This is a general rule, so additional 100 ft chords just increase the deflection angle by D/2. Therefore, it is very easy to find the deflection angles if a round value is chosen for D, and usually easy to set them off on the instrument. For example, if a curve begins at station 20+34.0 and ends at station 28+77.3, the first subchord is 100 - 34.0 = 66.0 ft to station 21, then 7 100 ft chords, and finally a subchord of 77.3 ft. The deflection angle from the P.C. to the P.T. for a 2° curve is 0.660 + 7 x 1.0 + 0.773 = 8.433 °, or 8° 26'. I have used the approximate relation δ = (c/100) (D/2) to find the deflection angles for the subchords.

The *long chord* C from P.C. to P.T. is a valuable check, easily determined with modern distance-measuring equipment. It is C = 2R sin (I/2), where I the total central angle. For the example, C = 2(2864.93)sin(8.433) = 840.32 ft. The length of the curve, by stations, is 843.30 ft. This figure can be checked by actual measurements in

the field. The actual arc length of the curve is (2864.93)(0.29437) = 843.34 ft. Note that this is the arc length on the centre line; for the rails, use $R \pm g/2$, where g = 4.7083 ft = 56.5 in = 1435 mm for standard gauge.

Before electronic calculators, small-angle approximations and tables of logarithms were used to carry out the computations for curves. Now, things are much easier, and I write the equations in a form suitable for scientific pocket calculators, instead of using the traditional forms that use tabular values and approximations.

A 1° curve has a radius of 5729.65 feet. Curves of 1° or 2° are found on high-speed lines. A 6° curve, about the sharpest that would be generally found on a main line, has a radius of 955.37 feet. On early American railroads, some curves were as sharp as 400 ft radius, or 14.4°. Street railways have even sharper curves. The sharpest curve that can be negotiated by normal diesel locomotives is not less than 250 ft radius, or 23°. It is not difficult to apply spirals, in which the change of curvature is proportional to distance, to the ends of a circular curve. Circular curves are a good first approximation to an alignment.

The centrifugal acceleration in a curve of radius R negotiated at speed v is $a = v^2/R$. If v is in mph, $a = 2.1511v^2/R = 3.754 \times 10^{-4}Dv^2$ ft/s^2, where D is degrees of curvature. This is normal to the gravitational acceleration of 32.16 ft/s^2, and the total acceleration is the vector sum of these. For comfort, a maximum ratio of a to g may be taken as 0.1 ($\tan^{-1}$ 5.71°). The overturning speed depends on the height of the centre of gravity, and occurs when a line drawn from the centre of gravity parallel to the resultant acceleration passes through one rail. The height of the centre of gravity of American railway equipment is 10 ft or less. Taking 10 ft as the height of the centre of gravity, a/g = 0.2354 ($\tan^{-1}$ 13/25°). Therefore, the overturning speed v_o can be estimated by $Dv_o^2 = 20{,}000$ and the comfort speed v_c by $Dv_c^2 = 8500$.

A curve may be superelevated by an amount s so that the resultant acceleration is more normal to the track. Exact compensation occurs only for one speed, of course. This angle of bank is given by $\tan\theta = a/g = 1.167 \times 10^{-5}Dv^2$, and $\sin\theta$ = s/gauge. Consider a 2° curve. For v = 60 mph, $\tan\theta = 0.08404$, $\sin\theta = 0.08375$ and s = 4.73 in. If the speed is greater than this, there will be an unbalanced acceleration, which will have a ratio of a/g of 0.1 at a speed v' given by $0.1 = 1.167 \times 10^{-5}D(v'^2 - v^2)$, or v' = 89 mph. The overturning speed on this curve is given by $(0.2354 + 0.08404) = (1.167 \times 10^{-5})Dv^2$, or v = 117 mph. Note that a large superelevation will cause the flanges of a slow-moving train to grind the lower rail. Superelevation is generally limited to 6 to 8 in maximum.

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Composed by James B. Calvert
Created 1 June 1999
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On this page: Wikipedia

curvature

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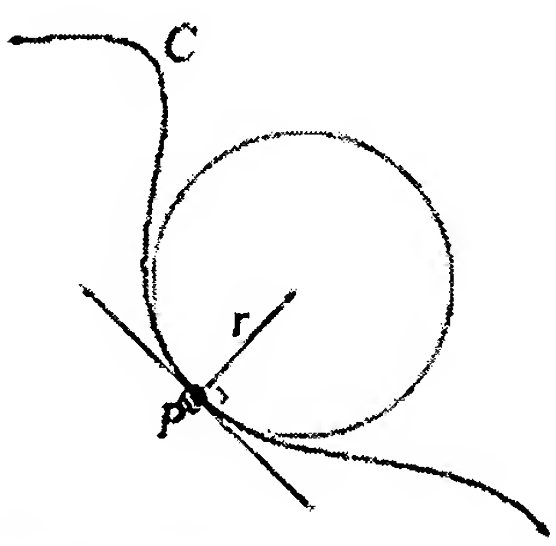
curvature

Curvature is the amount by which a geometric object deviates from being *flat*. The word *flat* might have very different meanings depending on the objects considered (for curves it is a straight line and for surfaces it is a Euclidean plane).

In this article we consider the most basic examples: the curvature of a plane curve and the curvature of a surface in Euclidean space. See the links below for further reading.

Curvature of plane curves



For a plane curve *C*, the curvature at a given point *P* has a magnitude equal to the *reciprocal* of the radius of an osculating circle (a circle that "kisses" or closely touches the curve at the given point), and is a vector pointing in the direction of that circle's center. The magnitude of curvature at points on physical curves can be measured in diopters (also spelled dioptre); a diopter has the dimension *one-per-meter*.

The smaller the radius *r* of the osculating circle, the larger the magnitude of the curvature ($1/r$) will be; so that where a curve is "nearly straight", the curvature will be close to zero, and where the curve undergoes a tight turn, the curvature will be large in magnitude.

A straight line has curvature 0 everywhere; a circle of radius *r* has curvature $1/r$ everywhere.

Local expressions

For a plane curve given parametrically as $c(t) = (x(t), y(t))$ the curvature is

$$\kappa = \frac{\dot{x}\ddot{y} - \dot{y}\ddot{x}}{(\dot{x}^2 + \dot{y}^2)^{3/2}}$$

where the dots denote differentiation with respect to t.

For a plane curve given implicitly as $f(x,y) = 0$ the curvature is

$$\kappa = \nabla \cdot \left(\frac{\nabla f}{\|\nabla f\|} \right)$$

that is, the divergence of the direction of the gradient of f. This last formula also gives the mean curvature of a hypersurface in Euclidean space (up to a constant).

Example

Consider the parabola $y = x^2$. We can parametrize the curve simply as $c(t) = (t,t^2) = (x,y)$.

Now:

$$\begin{aligned} \dot{x} &= 1, \quad \ddot{x} = 0 \\ \dot{y} &= 2t, \quad \ddot{y} = 2 \end{aligned}$$

Substituting

$$\kappa(t) = \frac{\dot{x}\ddot{y} - \dot{y}\ddot{x}}{(\dot{x}^2 + \dot{y}^2)^{3/2}}$$

$$\kappa(t) = \frac{1 \cdot 2 - (2t)(0)}{(1 + (2t)^2)^{3/2}} = \frac{2}{(1 + 4t^2)^{3/2}}$$

By observation we can identify that the area near the turning point of the parabola has sharpest curvature, with the curvature "flattening off" away from this area. This is reflected in the curvature; observe $\kappa(0) = 2$, but $\kappa(2) = \kappa(-2) = 2 / (4913)^{1/2} = 0.0285336\ldots$.

Curvature of space curves

A full treatment of curves embedded in an Euclidean space of arbitrary dimension (a *space curve*) is given in the article on parametric curves.

Curvature of surfaces in 3-space

For two-dimensional surfaces embedded in $\mathbf{R}^3$, there are two kinds of curvature: Gaussian curvature and **Mean curvature**. To compute these at a given point of the surface, consider the intersection of the surface with a plane containing a fixed normal vector at the point. This intersection is a plane curve and has a curvature; if we vary the plane, this curvature will change, and there are two extremal values - the maximal

and the minimal curvature, called the **principal curvatures**, k_1 and k_2, the extremal directions are called **principal directions**. Here we adopt the convention that a curvature is taken to be positive if the curve turns in the same direction as the surface's chosen normal, otherwise negative.

The **Gaussian curvature**, named after Carl Friedrich Gauss, is equal to the product of the principal curvatures, $k_1 k_2$. It has the dimension of 1/length^2 and is positive for spheres, negative for one-sheet hyperboloids and zero for planes. It determines whether a surface is locally convex (when it is positive) or locally saddle (when it is negative).

The above definition of Gaussian curvature is *extrinsic* in that it uses the surface's embedding in $\mathbf{R}^3$, normal vectors, external planes etc. Gaussian curvature is however in fact an *intrinsic* property of the surface, meaning it does not depend on the particular embedding of the surface; intuitively, this means that ants living on the surface could determine the Gaussian curvature. Formally, Gaussian curvature only depends on the Riemannian metric of the surface. This is Gauss' celebrated Theorema Egregium, which he found while concerned with geographic surveys and mapmaking.

An intrinsic definition of the Gaussian curvature at a point P is the following: imagine an ant which is tied to P with a short thread of length r. She runs around P while the thread is completely stretched and measures the length $C(r)$ of one complete trip around P. If the surface were flat, she would find $C(r) = 2\pi r$. On curved surfaces, the formula for $C(r)$ will be different, and the Gaussian curvature K at the point P can be computed as

$$K = \lim_{r \to 0} (2\pi r - \mathrm{C}(r)) \cdot \frac{3}{\pi r^3}.$$

The integral of the Gaussian curvature over the whole surface is closely related to the surface's Euler characteristic; see the Gauss-Bonnet theorem.

The **mean curvature** is equal to the sum of the principal curvatures, k_1+k_2, over 2. It has the dimension of 1/length. Mean curvature is closely related to the first variation of surface area, in particular a minimal surface like a soap film has mean curvature zero and soap bubble has constant mean curvature. Unlike Gauss curvature, the mean curvature depends on the embedding, for instance, a cylinder and a plane are locally isometric but the mean curvature of a plane is zero while that of a cylinder is nonzero.

Curvature of space

In cosmology, the concept of "curvature of space" is considered, which is the curvature of corresponding pseudo-Riemannian manifolds, see curvature of Riemannian manifolds.

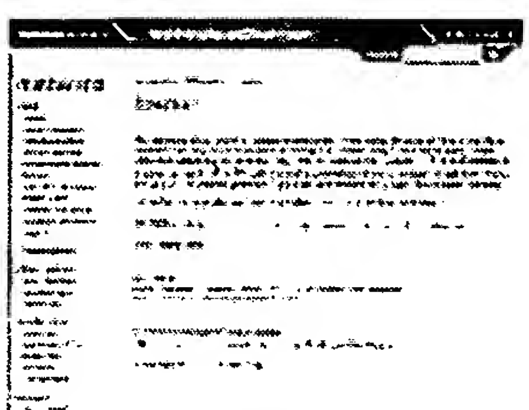
A space without curvature is called a "flat space" or Euclidean space. See also shape of the universe.

See also

- Curvature form for the appropriate notion of curvature for vector bundles and principal bundles with connection.
- Curvature of Riemannian manifolds for generalizations of Gauss curvature to higher-dimensional Riemannian manifolds.
- Curvature vector and geodesic curvature for appropriate notions of curvature of *curves in* Riemannian manifolds, of any dimension.
- Gauss map for more geometric properties of Gauss curvature.
- Gauss-Bonnet theorem for an elementary application of curvature.

Best of the Web

Some good **"curvature"** pages on the web:



Math
mathworld.wolfram.com

Mentioned In

curvature is mentioned in the following topics:

bowleg	space form
mean curvature	geodesic curvature
curvature of Riemannian manifolds	bend radius
dowager's hump (abnormal curvature of the spine)	sectional curvature
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